



ontario hydro research division

To
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STATE-OF-THE-ART SURVEY OF THE USE OF HEAT PUMP HEAT RECOVERY DEVICES FOR SPACE HEATING

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This is a state-of-the-art report on Exhaust Air Heat Recovery Heat Pump (EAHRHP) devices primarily for residential and commercial use. These devices provide mechanical ventilation to control humidity and improve indoor air quality, while recovering a large part of the exhaust air energy and returning it to the living space. There are currently no such devices manufactured in North America, but some are available in Europe. Canadian development efforts are ongoing.

1.0 INTRODUCTION

Interest in residential energy conservation has grown tremendously in recent years. One trend is towards better-sealed and better-insulated house envelopes. However, because of this tighter envelope, less fresh air can enter the house, and less stale air can escape. This may result in deteriorating air quality indoors. Some public health officials consider this trend an increasing health hazard/1/.

The problem of air contamination is only one aspect of indoor air quality. Another is excess humidity. In "loose" (less tightly sealed) houses, exfiltration of humid air can cause condensation and rot on wooden structural members. In tight houses, the trapped humidity causes condensation on windows and cool walls.

Mechanical ventilation is a basic solution to these problems. A simple exhaust fan will expel excess humidity in a controlled fashion, thus reducing condensation problems. A fan will also increase the fresh air intake to the house, reducing the concentration of most indoor pollutants. Unfortunately, the simple exhaust fan is very wasteful of energy. In a typical Toronto-area heating season, a fan exhausting air at the recommended rate will add \$100 to \$200 a year to the heating costs/2/.

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Some type of heat recovery device can be desirable to retain the energy savings of a well-insulated or well-sealed house while maintaining indoor air quality through mechanical ventilation.

2.0 BACKGROUND INFORMATION

There are two basic types of exhaust air heat recovery devices in use or under development. One is the Air to Air Heat Exchanger (ATAHE) in which the intake and exhaust air streams pass by each other and transfer heat. The other system is known as the Exhaust Air Heat Recovery Heat Pump (EAHRHP) and uses a vapour-compression refrigeration cycle to extract heat from the exhaust air stream. Schematics of these two types of devices can be found in Appendix B. Commercial models of EAHRHP devices are available in Europe, both for space and water heating. Some of these "water heating" units are designed to connect to a hydronic space heating system. Development efforts are continuing in Canada on a space heating model.

There are several types of ATAHEs on the market for residential and commercial use. Most of these use counter flow or cross flow heat exchanger designs. The cost of these units ranges from \$700 to \$2,000. The ducting system is simple and can be integrated with an existing hot air system. The common efficiency of such units is in the 60% range. ATAHEs can have problems with icing in cold weather, which can be overcome with proper defrost cycle control.

Since the intake air must flow in thermal contact with the exhaust air, the ATAHE does not necessarily produce a negative pressure in the house if the duct system is balanced, and therefore has little effect on exfiltration rates. There is a reduction in the overall humidity of the indoor air due to dilution with dry outdoor air. In addition, it has been shown that the ATAHE requires a tightly sealed house to produce energy cost savings/3/. This makes it less suitable for retrofit applications in older houses.

The EAHRHP uses a heat pump to extract heat from the exhaust air stream and rejects this heat to the living space (or to a water storage tank). The projected cost of \$1,000 for such a device is roughly equivalent to an ATAHE system/3/. Depending on the size, air-tightness, and present heating system of a house, energy cost savings could be on the order of \$100/yr. This gives an estimated simple payback period of 10 years for the EAHRHP device/3/.

The EAHRHP has several advantages over the ATAHE. The most important is the reduction or elimination of exfiltration due to

the negative indoor pressure. This reduces or eliminates the possibility of condensation-caused structural damage. Another advantage of the EAHRHP is that no specifically dedicated intake ducting is required since the incoming and outgoing air streams do not have to be in thermal contact. Fresh air intake is usually through increased infiltration.

It should be noted that there are potential disadvantages to creating a negative indoor pressure in a house. Downdrafts in fireplace and furnace chimneys are undesirable but are possible in tightly-sealed houses under negative pressure conditions. Also, if infiltration is increased too much, a house may feel 'drafty' to the occupants. These potential problems can be overcome by using an appropriately sized fresh-air intake, although this lessens the reduction in exfiltration.

A major advantage of EAHRHP systems is that the house does not have to be tightly sealed to save energy costs while providing ventilation/3/. This makes the EAHRHP very attractive for retrofit applications in older houses.

There are other advantages to a heat pump based heat recovery system. One is that with a few simple modifications it can supply a typical house's summer air conditioning needs. It is also possible to make a net energy gain from the exhaust air stream by cooling it below the outdoor temperature. Thus, a properly designed EAHRHP can carry up to 75% of a typical house heating load. The addition of resistive heating coils to the air intake or a small central electric furnace, makes the EAHRHP system a complete heating/cooling/ventilation system.

This report has been written to clarify the state-of-the-art in EAHRHP technology. A survey and discussion of commercially available models and development efforts is included, as well as some conclusions and recommendations.

3.0 SURVEY OF COMMERCIALY AVAILABLE UNITS

To identify commercially available units, a literature and manufacturers survey was conducted. It was found that there are at present no commercial EAHRHP models manufactured in North America. There is a Canadian development effort ongoing funded by the National Research Council of Canada (NRC) which will be discussed in a later section.

The commercial activity in EAHRHPs is based in Western Europe, principally France, Germany, Denmark and the Scandinavian countries. There are several manufacturers who make an EAHRHP water heater as an adaptation of existing ambient-air heat-pump

water heaters. It should be noted that virtually any hot-water EAHRHP can be connected to a hydronic space heating system (which are common in Europe). This comes closer to using the full energy content of the exhaust air stream than the typical domestic hot water heating load.

A hydronic plenum heater (HPH) could also be used to interface a water heating EAHRHP with a hot-air space heating system.

Two manufacturers were identified who make dedicated hot-air space heating EAHRHPs. Both are based in France. The manufacturers' claimed performance figures and other characteristics are summarized in Table A1 - Appendix A. Also included in this table is a water-heating EAHRHP model (#8) with an extra heat pickup coil in the tank. This can be used to interconnect with a hydronic heating system or HPH. The cost of the water heating unit is about \$900, and the space heating units vary from \$1,000 to \$1,500.

4.0 SURVEY OF DEVELOPMENT EFFORTS

The development of commercial EAHRHP units for the North American market has lagged behind Europe. This is primarily due to lower energy costs in North America and building codes in European countries that require mechanical ventilation.

There is, however, a major Canadian development effort ongoing to produce and market a commercial space-heating EAHRHP. The project is funded by the National Research Council of Canada.

The first phase of this project was a detailed feasibility study/3/ which examined all aspects of the EAHRHP as a potentially commercially viable product. Included were a detailed technical study to optimize the design of the device; thorough economic analysis to indicate payback periods for various configurations; and an in-depth marketing survey and strategy.

NRC has contracted the development of a working prototype to KeepRite Inc, a Brantford, Ontario-based manufacturer of HVAC equipment. One working prototype has been built as of the time of writing this report. The characteristics of this prototype are included in Table A1 (#10).

There was an inconclusive effort made by Scanada House Inspection services of Ottawa to build a prototype residential EAHRHP. Low COP's and icing problems led to difficulties with their approach. Scanada's development effort is currently stalled due to lack of funding.

The NRC/KeepRite prototype has an average COP of around 2.5, which makes it economically viable according to the original feasibility study. The extremely large temperature drop across the evaporator coil recommended in the feasibility study has not been achieved due to icing problems. Passive defrosting is accomplished by turning off the compressor and allowing the warm exhaust air to melt the ice. The defrost cycle time is approximately 1-1/2 hours.

The next phase of the development effort is a field trial of the prototype. Then design refinements will be made and a commercial unit may be produced and marketed.

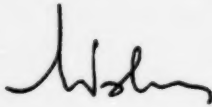
5.0 CONCLUSIONS AND RECOMMENDATIONS

1. There are currently no manufacturers of Exhaust Air Heat Recovery Heat Pumps in North America.
2. There are several brands of commercially available Exhaust Air Heat Recovery Heat Pumps in Europe. Two manufacturers were identified who make hot-air space heating models. Four manufacturers were identified who produce DHW Exhaust Air Heat Recovery Heat Pumps devices.
3. The cost of the Exhaust Air Heat Recovery Heat Pump appears to be competitive with the Air-to-Air Heat Exchanger. However, the Exhaust Air Heat Recovery Heat Pump has significant advantages over the Air-to-Air Heat Exchanger which make it the system of choice where mechanical ventilation is required in older buildings for humidity control and air quality improvement or where energy savings are to be maximized.
4. There is a Canadian effort underway, funded by NRC, to develop a commercially viable space heating Exhaust Air Heat Recovery Heat Pump.
5. The best current estimate of energy cost savings using an Exhaust Air Heat Recovery Heat Pump is approximately \$100/yr. This gives an estimated simple payback period of 10 years. This, however, does not include the value of the benefits derived from mechanical ventilation. These benefits are primarily humidity control to prevent structural damage, and indoor air quality improvement. It is difficult to place a dollar value on these gains.
6. There is the potential for a significant new load for Ontario Hydro from Exhaust Air Heat Recovery devices, since future building codes will probably require mechanical

ventilation of residential buildings. Promotion of the development of Exhaust Air Heat Recovery Heat Pump devices by Ontario Hydro could well assist the growth of this load.

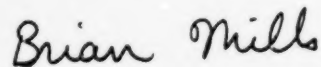
7. It is important to note that all the Exhaust Air Heat Recovery devices currently available or under development are electrical systems. Therefore, the Exhaust Air Heat Recovery market is currently free of any competition with electricity. This gives Ontario Hydro an opportunity to supply the space heating requirements of low-energy houses.

Reviewed:



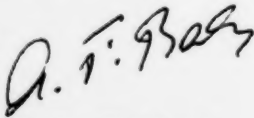
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APPENDIX A

TABLE OF EXHAUST AIR HEAT
RECOVERY HEAT PUMPS
SPECIFICATIONS

TABLE A1

TECHNICAL SPECIFICATIONS OF EXHAUST AIR HEAT RECOVERY HEAT PUMPS
- COMMERCIALY AVAILABLE (1-9) AND UNDER DEVELOPMENT (10)

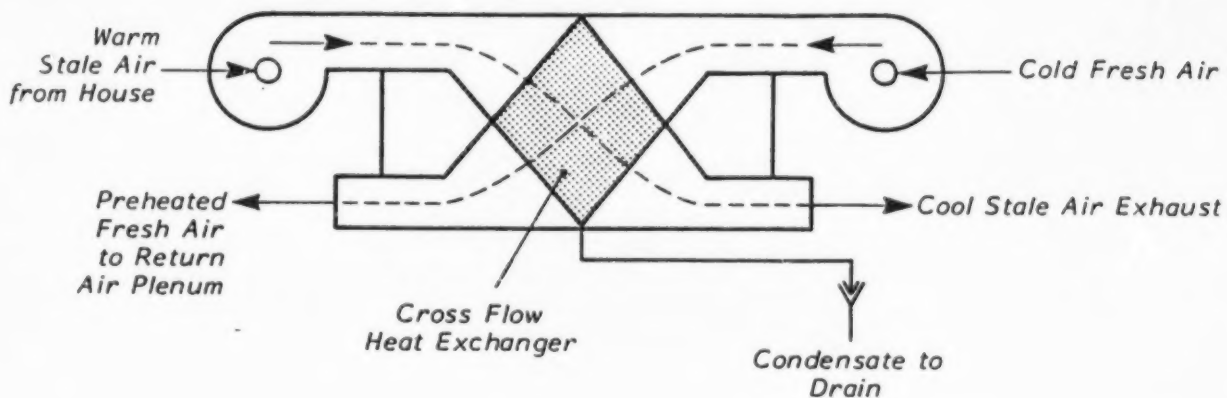
Manufacturer	1 DE Dietrich BAE 1500	2 DE Dietrich BAE 2300	3 Mather SFO 180	4 Mather SFO 350	5 Mather SF 180	6 Mather SF 350	7 Aquorex by Elektro Standard	8 Aquorex 270 by Elektro Standard	9 Metro (Typical)	10 MRC Prototype
Country	France	France	France	France	France	France	Sweden	Sweden	Denmark	Canada
Type	hot air	hot air	water	water	hot air	hot air	hot water	hot water	hot water	hot air
Claimed COP	1.9-2.9	2-3	2.83	2.75	2.83	2.75	3	3	3	2.5
Conditions for claimed COP	7°C inlet air 508 B.H.	7°C inlet air 502 B.H.	50°C outlet air	50°C outlet water	35°C outlet air	35°C outlet air	50°C outlet water	50°C Temp outlet water	52°C outlet water	N/A
Temperature drop across evaporator (°C) Est.	15	15	20	20	20	20	10	15	N/A	15
H P Capacity (Watts)	1500	2300	2100	3250	2100	3250	1000	3600	1400	1600
Air Flow Rate (m ³ /h)	200	300	180-220	300-350	180-220	300-350	80-200	100-300	250-350	130-255
Supply Voltage (Volts)	220	220	220	220	220	220	220	220	220	240
Refrigerant	R22	R22	R502	R22	R502	R22	R12	N/A	N/A	R22
Controls	thermostatic	thermostatic	N/A	M/A	M/A	M/A	thermostatic	thermostatic	thermostatic	N/A
Comments	-COP derived from power figures -attic mounted -wt 90 kg	-COP derived from power figures -attic mounted -wt 100 kg	-intended for hydronic heating -1250 W electric air preheaters available	-intended for hydronic heating -1250 W elec- tric air preheaters available	-1250 W electric air preheaters available	-1250 W electric air preheaters available	-DHW model; under test at UMED -included for comparison	-circulating pump for hydronic heating; loop included	-units available with hydronic coil installed -units available with ATARE also	-under development

NOTE: N/A means information not available

APPENDIX R

SCHEMATICS OF EXHAUST AIR
HEAT RECOVERY SYSTEMS

AIR TO AIR HEAT EXCHANGER



EXHAUST AIR HEAT RECOVERY HEAT PUMP

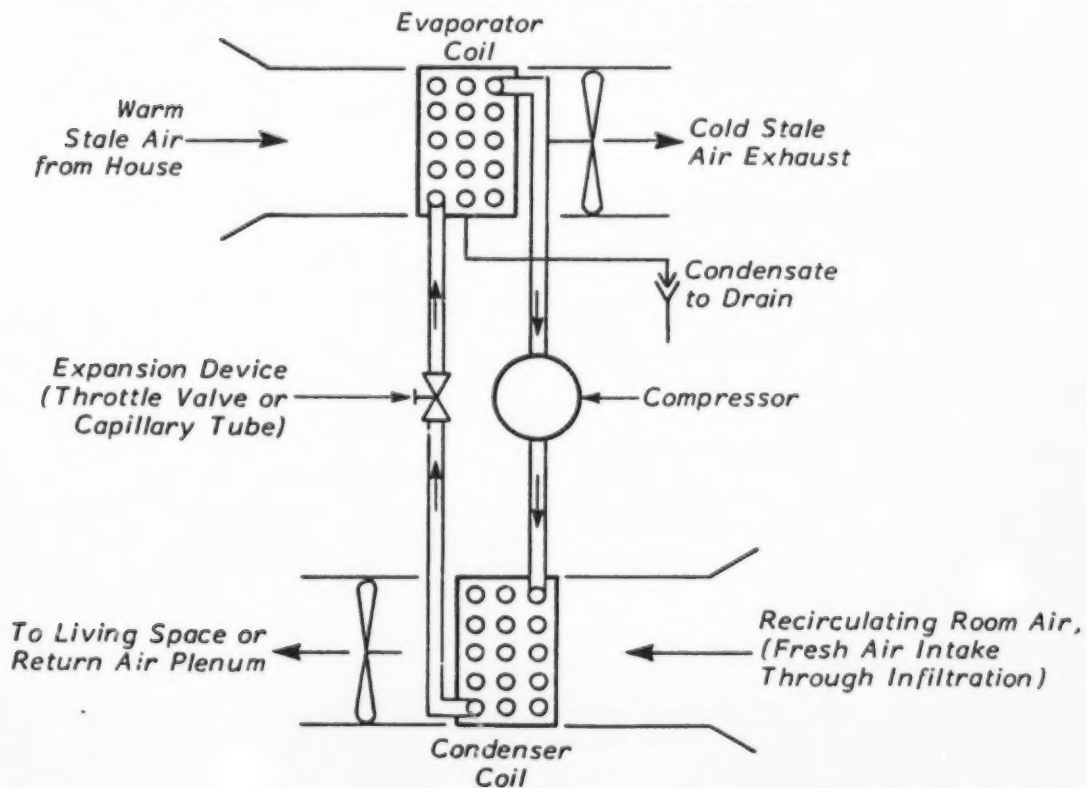


FIGURE B1

SYSTEM SCHEMATICS - AIR TO AIR HEAT EXCHANGER
AND EXHAUST AIR HEAT RECOVERY HEAT PUMP